(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 August 2002 (22.08.2002)

PCT

(10) International Publication Number
WO 02/065027 A2

(51) International Patent Classification[7]: F25B

(21) International Application Number: PCT/US02/04070

(22) International Filing Date: 12 February 2002 (12.02.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/782,351 12 February 2001 (12.02.2001) US
09/975,573 11 October 2001 (11.10.2001) US

(71) Applicants: SOCIETE DES PRODUITS NESTLE S.A. [CH/CH]; P.O. Box 353, CH-1800 Vevey (CH). WATLOW POLYMER TECHNOLOGIES [US/US]; 1265 East Sanborn, Winona, MN 55987 (US).

(72) Inventors: LAKEN, Keith; Route 6, Box 31B, Winona, MN 55987 (US). SCHLESSELMAN, John, W.; S 3104 North Shore Drive, Fountain City, WI 54629 (US). VON ARX, Theodore; Route 1, Box 170, La Crescent, MN 55974 (US). DAMIANO, Dominick; 141 Lake Place South, Danbury, CT 06810 (US). SHEEHAN, Brita, Frangsmyr; 34 Beard Drive, New Milford, CT 06776 (US). ZHANG, Hua; 34 Morey Road, New Milford, CT 06776 (US).

(74) Agent: CRONK, Peter, J.; Duane Morris LLP, One Liberty Place, Philadelphia, PA 19103-7396 (US).

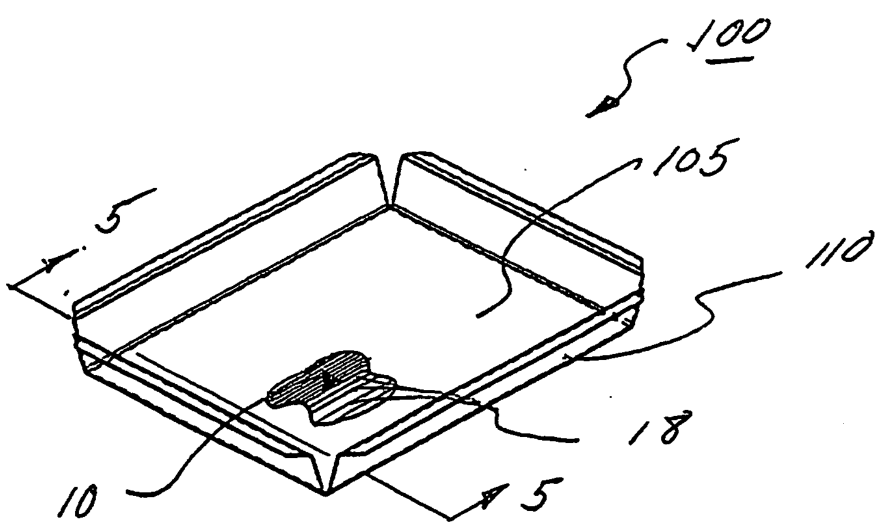
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: FORMABLE THERMOPLASTIC LAMINATE HEATING TRAY ASSEMBLY SUITABLE FOR HEATING FROZEN FOOD



(57) Abstract: A heating element assembly in the form of a heating tray and a method of manufacturing heating tray assemblies. The heating tray may be used for defrosting and heating pans such as so-called "half-pans" of frozen food products. The preferred heating tray is configured to fit precisely around a standard thin foil half-pan container, thus optimizing heat transfer between the heating tray and the food product. The varied surface watt density of the heating tray allows for accurate heat placement such that the food product can be evenly warmed while avoiding over warming or burning, particularly at the corners and edges. A preferred embodiment of the heating tray includes two resistance heating elements. The first heating element is a temperature booster used for defrosting and heating, while the second heating element is a maintenance heater to maintain heated food at a serving temperature.

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FORMABLE THERMOPLASTIC LAMINATE HEATING TRAY ASSEMBLY SUITABLE FOR HEATING FROZEN FOOD

Field of the Invention

This invention relates to electrical resistance heating elements, and more particularly to formable thermoplastic laminate heating element assemblies.

Background of the Invention

Methods for providing reformable heating element assemblies are described in Applicant's co-pending application S/N 09/642,215, herein incorporated in its entirety by reference.

In the food service industry, thin foil pans, also known as "half pans" are commonly used to distribute prepared food products such as lasagna and macaroni and cheese. These products are often distributed in a frozen state to prevent spoiling. Typically, half pans of frozen food products are heated in conventional ovens. However, oven heat controls and oven thermodynamics have been known to unevenly heat the various food products. Consequently, food products may be burned or crusted at the edges and undercooked in the center.

Therefore, improved apparatus and methods for heating pans of frozen food products are desirable. The ideal heating apparatus would provide intimate contact between the contents and the bottom and side walls of the half pan. The preferred design would also provide varied surface watt density to allow for better heat placement, and more uniform cooking of frozen food. Finally, the preferred heating apparatus would include multiple resistance heating elements to provide both initial temperature boosting for defrosting and heating, and maintenance heating for maintaining heated food at a given warming temperature.

Summary of the Invention

The present invention provides a heating element assembly in the form of a heating tray and a method of manufacturing heating tray assemblies. The heating tray may be used for defrosting and heating so-called "half-pans" of frozen food products. The preferred heating tray is configured to fit precisely around a standard thin foil half-pan container, thus optimizing heat transfer between the heating tray and the food product. The varied surface watt density of the heating tray allows for accurate heat placement such that the food product can be evenly warmed while avoiding over warming or burning, particularly at the corners and edges. A preferred embodiment of the heating tray includes two resistance heating

elements. The first heating element is a temperature booster used for defrosting and heating, while the second heating element is a maintenance heater to maintain heated food at a serving temperature.

A heating element assembly in accordance with a first embodiment of the invention includes a supporting substrate and a plurality of circuit paths, each circuit path comprising electrical resistance heating material attached to the supporting substrate, wherein at least one of the circuit paths has terminal end portions. At least one of the circuit paths continues onto a first flap portion of the resistance heating element assembly and is capable of rotation about a first axis of rotation. The resistance heating element is disposed between first and second thermoplastic sheets. The thermoplastic sheets and resistance heating element are joined together to form a reformable structure. The reformable structure is formed into a final element assembly configuration, such as by thermoforming, bending, or drawing, etc., whereby at least the first flap portion is rotated about the first axis to provide resistance heating in at least two planes.

The present invention as described above provides several benefits. A plurality of intricate resistance circuit paths of one or more resistance heating materials may be secured to a planar supporting substrate and then joined between thermoplastic sheets, wherein the planar resistance heating element may then be reformed with the laminated structure to provide heat on a plurality of heat planes.

These heating structures provide intimate contact between the contents of the heating structures and the heat source, thereby providing inherent energy consumption advantages as well as the ability to intimately locate secondary devices such as thermistors, sensors, thermocouples, RTDs, etcetera, in proximity to the contents being heated or conditions being observed or recorded.

The heating element assembly also allows for an infinite number of circuit path shapes, allowing the circuit path to correspond to the general shape of a desired end product utilizing the heating element assembly. The heating element assembly may be folded to occupy a predefined space in an end product and to provide heat in more than one plane, thermoformed into a desired three dimensional heated plane, or stamped or die cut into a predetermined flat shape which may, then, be folded or thermoformed into a desired three dimensional heated shape. The heating element assembly thereby emulates well known sheet metal processing or known plastic forming processes and techniques.

The heating element assembly according to the present invention may also be over molded in a molding process whereby the resistance heating element is energized to soften the thermoplastic sheets and the heating element assembly is over molded with a thermoplastic to form a detailed molded structure. The energizing and overmolding steps

may be timed such that the thermoplastic sheets and over molded thermoplastic form a substantially homogenous structure accurately capturing and positioning the resistance heating element within the structure. Alternatively, the heating element assembly may soften during mold flow without additional energizing.

In another embodiment of the invention a resistance heating lid is provided in combination with the heating tray configuration for improved heating of foods contained therein.

In yet another embodiment of the invention, a method for manufacturing a sheet of heating element assemblies is provided, the sheet of heating element assemblies comprising a first thermoplastic sheet, a second thermoplastic sheet affixed to the first thermoplastic sheet, and a sheet of resistance heating elements secured between and to the first and second thermoplastic sheets. The sheet of resistance heating elements includes a supporting substrate and a plurality of circuit paths attached to the substrate in spaced pairs, each circuit path comprising an electrical resistance heating material, at least one of the circuits of each pair of circuit paths having terminal end portions, at least one of each pair of circuit paths continuing onto a first flap portion of a resistance heating element capable of rotation about a first axis of rotation. The thermoplastic sheets are laminated together such that the sheet of resistance heating elements is secured between and to the first and second thermoplastic sheets to form a sheet of reformable heating element assemblies.

The sheet of heating element assemblies of this embodiment provides several benefits. The sheet may be inexpensively and efficiently produced using mass production techniques. The sheet may be collected into a roll, allowing the later separation and use of individual heating element assemblies or group of heated element assemblies as described above. The sheet, may be further, or alternatively, processed using various secondary fabrication techniques, such as stamping, die cutting, or overmolding.

The above and other features of the present invention will be better understood from the following detailed description of the preferred embodiments of the invention which is provided in connection with the accompanying drawings.

A Brief Description of the Drawings

The accompanying drawings illustrate preferred embodiments of the invention, as well as other information pertinent to the disclosure, in which:

FIG. 1 is a top plan view of a pair of resistance wires disposed in predetermined circuit paths according to an exemplary embodiment of the invention;

FIG 1a is a top plan view of another embodiment of a resistance wire disposed in a

predetermined circuit path according to an exemplary embodiment of the invention;

FIG. 2 is a front perspective view of a preferred programmable sewing machine and computer for manufacturing resistance heating elements;

FIG. 3 is an isometric view of an embodiment of the heating element assembly according to the invention, with a portion of a top laminate surface removed to reveal a portion of the resistance heating element;

FIG. 4 is a top plan view of the heating element assembly shown in FIG. 3.;

FIG. 5 is a partial cross-sectional elevation view of the heating element assembly shown in FIG. 3, taken along line 5-5;

FIG. 6 is a partial cross-sectional view of a multi-layered heating element assembly according to the invention;

FIG. 7 is a diagram of an exemplary method of manufacturing a sheet of heated element assemblies according to the invention;

FIG. 8 is a diagram of a sheet of resistance heating elements shown in partial view according to the invention;

FIG. 9 is a top plan view of a resistance heating element assembly wherein the laminated structure has been cut to form a profile for a heating container which may be folded to form a three dimensional heater assembly;

FIG. 10 is a top plan view of a heating element assembly including the resistance heating element of FIG. 9 wherein a portion the top laminated surface has been removed to show the resistance heating element, before being formed into a final configuration;

FIG. 11 is an isometric view of a heating element assembly formed from the cut heating element of FIG. 10;

FIG. 12 is top plan view of a heating element assembly showing the varying surface watt density provided by resistance heating wires;

FIG. 13 is a top plan view of an embodiment of a heating lid assembly in accordance with the invention;

FIG. 14 is an isometric view of the embodiment of the heating lid assembly shown in FIG. 13;

FIG. 15 is a performance graph of an exemplary heating assembly in accordance with the invention; and

FIG. 16 is as a performance graph of the heating assembly of FIG. 12, in which the heating assembly is used to heat a frozen entree.

Detailed Description of Preferred Embodiments

The present invention provides a thermoplastic laminate heating element assembly

including resistance heating elements, in the form of a heating tray. As used herein, the following terms are defined:

"Laminate" means to unite, for example, layers of lamina via bonding them together, usually with heat, pressure and/or adhesive. It normally is used to refer to flat sheets, but also can include rods and tubes. The term refers to a product made by such bonding;

"Serpentine Path" means a path which has one or more curves for increasing the amount of electrical resistance material in a given volume of polymeric matrix, for example, for controlling the thermal expansion of the element;

"Melting Temperature" means the point at which a fusible substance begins to melt;

"Melting Temperature Range" means the temperature range over which a fusible substance starts to melt and then becomes a liquid or semi-liquid;

"Degradation Temperature" means the temperature at which a thermoplastic begins to permanently lose its mechanical or physical properties because of thermal damage to the polymer's molecular chains;

"Evacuating" means reducing air or trapped air bubbles by, for example, vacuum or pressurized inert gas, such as argon, or by bubbling the gas through a liquid polymer.

"Fusion Bond" means the bond between two fusible members integrally joined, whereby the polymer molecules of one member mix with the molecules of the other. A Fusion Bond can occur, even in the absence of any direct or chemical bond between individual polymer chains contained within said members;

"Fused" means the physical flowing of a material, such as ceramic, glass, metal or polymer, hot or cold, caused by heat, pressure or both;

"Electrofused" means to cause a portion of a fusible material to flow and fuse by resistance heating;

"Stress Relief" means reducing internal stresses in a fusible material by raising the temperature of the material or material portion above its stress relief temperature, but preferably below its Heat Deflection Temperature;

"Flap" or "Flap Portion" means a portion of an element which can be folded without damaging the element structure; and

"Half Pan" container means a thin foil container commonly used for commercial distribution of ready-made frozen food products, such as lasagna and macaroni and cheese.

Resistance Heating Element

With reference to Figures 1-11, there is shown a first embodiment of a resistance heating element 10, preferably having about 50-95% of the surface area of a thin foil half pan. The preferred resistance heating element 10 may include a regulating device for controlling

electric current. Such a device can include, for example, a thermistor, a thermocouple, or a RTD for preventing overheating of the polymeric materials disclosed in this invention, or a self-regulating material. The resistance heating elements 10 of this invention can take on any number of shapes and sizes, including squares, ovals, irregular circumference shapes, tubes, cup shapes and container shapes. Sizes can range from less than one inch square to 21 in. x 26 in., and greater sizes can be available if multiple elements are joined together. Greater sizes are also available with roll, or continuous element forms.

As shown in FIG. 1, the resistance heating element 10 includes one or more resistance wires 12 and 13 disposed in predetermined circuit paths. The ends of each resistance wire 12 and 13 are coupled to a pair of electrical connectors 15 and 16 using known techniques such as, riveting, grommeting, brazing, clinching, compression fitting or welding. The circuit includes a resistance heating material, which may be a resistance heating wire 12 or 13 wound into a serpentine path containing, for example, about 1-200 windings, or, a resistance heating material, such as ribbon, a foil or printed circuit, or powdered conducting or semi-conducting metals, polymers, graphite, or carbon, or a conductive coating or ink. Other suitable alternatives may include conductive polymer layers carbon or graphite powder, fibers, scrim, woven and non-woven fabrics. For example, a thermoplastic or thermosetting polymer having a powdered carbon based material forming a circuit path therein, could be used. Preferably the resistance heating wires 12 and 13 include a Ni-Cr alloy, although certain copper, steel, and stainless-steel alloys could be suitable. A positive temperature coefficient wire or conductive polymer may also be suitable. The resistance heating wires 12 and 13 can be provided in separate parallel paths, or in separate layers. Whatever material is selected, it should be electrically conductive, and heat resistant. It should also be resilient to subsequent forming operations, either on its own, as in the base of a wire or scrim, or encapsulated within a polymer. A tensile strength of at least about 10,000 psi, and preferably at least about 50,000 psi for the fiber or resulting composite is helpful. (See ASTM D3379, D3039)

Alternatively, continuous or closed loop heating wires may be provided, in which case current is induced into the heating element by means such as high frequency radiation or magnetic induction.

Substrates

As used herein, the term "supporting substrate" refers to the base material on which the resistance material, such as wires, are applied, or impregnated within, as is the case with graphite powder for example. The supporting substrate 11 of this invention should be capable of being pierced, penetrated, or surrounded, by a sewing needle for permitting the

sewing operation. Other than this mechanical limitation, the substrates of this invention can take on many shapes and sizes. Flat flexible substrates are preferably used for attaching an electrical resistance wire with a thread. Non-plastic materials, such as glasses, semiconductive materials, and metals, can be employed so long as they have a pierceable cross-sectional thickness, e.g., less than 0.010 inch -0.020 inch, or a high degree of porosity or openings therethrough, such as a grid, scrim, woven or non-woven fabric, for permitting the sewing needle of this invention to form an adequate stitch. The supporting substrate 11 of this invention need not necessarily contribute to the mechanical properties of the final heating element, but may contain high strength fibers. Such fibers could contain glass, aramid fibers woven or melt-bonded or joined with an adhesive to form a scrim, woven or non-woven mat.

Alternatively, the supporting substrate 11 of this invention may contain ordinary, natural, or synthetic fibers, such as cotton, wool, silk, rayon, nylon, polyester, polypropylene, polyethylene, etc. The supporting substrate may also comprise a synthetic fiber such as Kevlar or carbon fibers that have good thermal uniformity and strength. The advantage of using ordinary textile fibers, is that they are available in many thicknesses and textures and can provide an infinite variety of chemistry, porosity and melt-bonding ability. The fibers of this invention, whether they be plastic, natural, ceramic or metal, can be woven, or spun-bonded to produce non-woven textile fabrics.

Specific examples of supporting substrates 11 useful in this invention include polymer, ceramic, glass or metallic films, such as non-woven fiberglass mats bonded with an adhesive or sizing material such as model 8440 glass mat available from Johns Manville, Inc. Additional substrates can include polymer impregnated fabric organic fabric weaves, such as those containing nylon, rayon, or hemp etc., porous mica-filled plate or sheet, and thermoplastic sheet film material. In one embodiment, the supporting substrate 11 contains a polymeric resin which is also used in either the first thermoplastic sheet 110 or second thermoplastic sheet 105, or both of a heated element assembly 100 described below. Such a resin can be provided in woven or non-woven fibrous form, or in thin sheet material having a thickness of 0.020 inch or less. Thermoplastic materials can be used for the supporting substrate 11 which will melt-bond or liquefy with the thermoplastic sheets 110, 105, so as to blend into a substantially uniform structure.

Sewing Operation

With reference to FIG. 2, the preferred programmable sewing machine 20 will now be described. The preferred programmable sewing machine is one of a number of powerful embroidery design systems that use advanced technology to guide an element designer through design creation, set-up and manufacturing. The preferred programmable sewing machine 20 is linked with a computer 22, such as a personal computer or server, adapted to

activate the sewing operations. The computer 22 preferably contains or has access to, embroidery or CAD software for creating thread paths, borders, stitch effects, etc.

The programmable sewing machine 20 includes a series of bobbins 24 for loading thread and resistance heating wire or fine resistance heating ribbon. Preferably, the bobbins 24 are pre-wound to control tension since tension, without excessive slack, in both the top and bottom bobbins 24 is very important to the successful capturing of resistance heating wire on a substrate. The thread used should be of a size recommended for the preferred programmable sewing machine. It must have consistent thickness since thread breakage is a common mode of failure in using programmable sewing machines. An industrial quality nylon, polyester or rayon thread is highly desirable. Also, a high heat resistant thread may be used, such as a Kevlar thread or Nomex thread known to be stable up to 500°F and available from Saunders Thread Co. of Gastonia, North Carolina.

The programmable sewing machine preferably has 1-20 heads and can measure 6 foot in width by 19 feet long. The sewing range of each head is about 10.6 inches by 26 inches, and with every other head shut off, the sewing range is about 21 inches by 26 inches. An acceptable programmable sewing machine is the Tajima Model No. TMLG116-627W (LT Version) from Tajima, Inc., Japan.

The preferred method of capturing a resistance heating wire 12, 13 onto a supporting substrate 11 in this invention will now be described. First, an operator selects a proper resistive element material, for example, Ni-Cr wire, in its proper form. Next, a proper supporting substrate 11, such as 8440 glass mat, is provided in a form suitable for sewing. The design for the element is preprogrammed into the computer 22 prior to initiating operation of the programmable sewing machine 20. As with any ordinary sewing machine, the programmable sewing machine 20 of this invention contains at least two threads, one thread is directed through the top surface of the supporting substrate, and the other is directed from below. The two threads are intertwined or knotted, ideally somewhere in the thickness of the supporting substrate 11, so that one cannot view the knot when looking at the stitch and the resulting resistance heating element 10. As a top needle penetrates the substrate 11 and picks up a loop of thread mechanically with the aid of the mechanical device underneath, it then pulls it upward toward the center of the substrate 11 and if the substrate is consistent and the thread tension is consistent, the knots will be relatively hidden. In a preferred embodiment of this invention, the resistance heating wire 12, 13 is provided from a bobbin in tension. The preferred programmable sewing machine 20 of this invention provides a third thread bobbin for the electrical resistance wire 12, 13 so that the programmable sewing machine 20 can lay the resistance wire 12, 13 down just in front of the top needle. The preferred operation of this invention provides a zig zag or cross stitch pattern, whereby the

top needle criss-crosses back and forth as the supporting substrate 11 is moved, similar to the way an ornamental rope is joined to a fabric in an embroidery operation. A simple looping stitch with a thread 14 is also shown. By guiding the top needle over either side of the resistance heating wire 12, 13 the heating wire 12, 13 is captured in a very effective manner, the process being computer controlled so that the pattern can be electronically downloaded into the computer 22 and automatically sewn onto a substrate of choice.

The programmable sewing machine 20 can sew an electrical resistance heating wire 12, 13 having a diameter or thickness of 0.005 inch - 0.25 inch, onto a supporting substrate 11 at a rate of about 10-500 stitches per minute, saving valuable time and associated cost in making resistance heating elements.

The ability to mechanically attach resistive elements, such as wires, films and ribbons, to substrates provides a multitude of design possibilities in both shape and material selection. Designers may mix and match substrate materials by selecting their porosity, thickness, density and contoured shape with selected resistance heating materials ranging in cross-section from very small diameters of about 0.005 inch to rectangular and irregular shapes, to thin films. Also, secondary devices such as circuits, including microprocessors, fiberoptic fibers or optoelectronic devices, (LEDs, lasers) microwave devices (power amplifiers, radar) and antenna, high temperature sensors, power supply devices (power transmission, motor controls) and memory chips, could be added for controlling temperature, visual inspection of environments, communications, and recording temperature cycles, for example. The overall thickness of the resistance heating element is merely limited by the vertical maximum position of the needle end, less the wire feed, which is presently about 0.5 inch, but may be designed in the future to be as great as 1 inch or more. Resistive element width is not nearly so limited, since the transverse motion of the needle can range up to one foot or more.

The use of known embroidery machinery in the fabrication of resistance heating elements allows for a wide variety of raw materials and substrates to be combined with various resistance heating materials. The above construction techniques and sewing operation also provide the ability to manufacture multi-layered substrates, including embedded metallic and thermally conductive layers with resistance wires wrapped in an electrically insulating coating, so as to avoid shorting of electric current. This permits the application of a resistance heating wire to both sides of the thermally conductive metallic layer, such as aluminum foil, for more homogeneously distributing resistance heat.

Thermoplastic Laminate Heating Element Assembly and Heating Tray Construction

FIG. 3 shows an exemplary heating element assembly 100, in the form of a heating

tray, according to the invention. The heating element assembly 100 includes a resistance heating element 10 disposed between laminated first and second thermoplastic sheets 105, 110. For illustrative purposes, the first thermoplastic sheet 105 is shown partially removed from the second thermoplastic sheet 110. The resistance heating element 10, described above, at least substantially encompasses the circuit paths, defined by resistance wires 12 and 13.

The supporting substrate of the resistance heating element 10 has a thickness between 0.005 inch, and 0.25 inch, and preferably is 0.025 inch thick. The supporting substrate should be flexible, either under ambient conditions or under heat or mechanical stress, or both. A thin semi-rigid heating element assembly 100 allows for closer proximity of the resistance heating wires 12 and 13 to an object to be heated when the heating element assembly is formed into a final element assembly, such as a such as a half pan. Because less heat needs to be generated by the resistance heating element 10 to provide heat to the outer surfaces of a thin heating element assembly 100, materials having lower RTI (Relative Thermal Index) ratings can be successfully used in thin heating element assemblies.

The thermoplastic sheets 105, 110 are laminated to each other to secure resistance heating element 10 and to form a reformable continuous element structure. The thermoplastic sheets 105, 110 may be heated and compressed under sufficient pressure to effectively fuse the thermoplastic sheets together. A portion of this heat may come from energizing the resistance heating element 10. Alternatively, thermosetting polymer layers could be employed, such as B-stage epoxy sheet or pre-preg material.

Preferred thermoplastic materials include, for example: fluorocarbons, polypropylene, polycarbonate, polyetherimide, polyether sulfone, polyaryl-sulfones, polyimides, and polyetherkeytones, polyphenylene sulfides, polyether sulfones, and mixtures and co-polymers of these thermoplastics. An acceptable thermoplastic polyetherimide is available from the General Electric Company under the trademark ULTEM.

It is further understood that, although thermoplastic materials are preferable for forming fusible layers because they are generally heat-flowable, some thermoplastics, notably polytetraflouroethylene (PTFE) and ultra high-molecular-weight polyethylene (UHMWPE) do not flow under heat alone. Also, many thermoplastics are capable of flowing without heat, under mechanical pressure only.

Acceptable results were achieved when forming a heating element assembly under the conditions indicated in TABLE 1 as follows:

<u>TABLE</u>

MATERIAL	THICKNESS OF SHEET (inch)	PRESSURE (PSI)	TIME (minutes)	TEMP. (°F)
Polypropylene	0.009	22	10	350
Polycarbonate	0.009	22	10	380
Polysulfone	0.019	22	15	420
Polyetherimide	0.009	44	10	430
Polyethersulfone	0.009	44	10	460

Where no vacuum was applied, "thickness" is the thickness of the thermoplastic sheets in inches, "pressure" represents the amount of pressure (psi) applied to the assembly during lamination, "temperature" is the temperature applied during lamination, and "time" is the length of time that the pressure and heat were applied. It will be understood the above-identified material thicknesses used in forming exemplary embodiments of the assembly described herein are merely provided by way of example. Materials of differing thicknesses may also be used to achieve acceptable results without departing from the scope of the invention.

The first and second thermoplastic sheets 105, 110 and resistance heating element 10 of the heating element assembly 100 may also be laminated to each other using an adhesive. In one embodiment of the present invention, an adhesive, which may be a ultraviolet curable adhesive, may be used to attach the materials together. The adhesive may be disposed between the resistance heating element 10 and the first thermoplastic sheet 105 and between the resistance heating element 10 and the second thermoplastic sheet 110, as well as between areas of the thermoplastic sheets 105, 110 which are aligned to be in direct contact. An ultraviolet curable adhesive may be used that is activated by ultraviolet light and then begins to gradually cure. In this embodiment of the present invention, the adhesive may be activated by exposing it to ultraviolet light before providing the second of the thermoplastic sheets 105, 110. The thermoplastic sheets 105, 110 may then be compressed to substantially remove any air from between the sheets 105, 110 and to secure resistance heating element 10 therebetween.

Figure 6 illustrates that a heating element assembly 100a may include a plurality of heated layers. A second resistance heating element 10a may be laminated between one of thermoplastic sheets 105,110 and a third thermoplastic sheet 115.

The thicknesses of thermoplastic sheets 105, 110 and the thickness of supporting substrate 11 and resistance heating wires 12 and 13 are preferably selected to form a

reformable continuous element structure that maintains its integrity when the element is formed into a final element structure. The preferred heating element assembly 100 according to the invention, then, is a semi-rigid structure in that it may be reformed, such as by simply molding, folding or unfolding under heat, pressure, or a combination thereof as required by the chosen thermoplastics, into a desired shape without sacrificing structural integrity.

Heating trays 100 according to the present invention provide several advantages over non-rigid and rigid containers which do not include a heat source. The heat source, i.e., the resistance heating element 10, intimately surrounds the contents of a tray 100, which may be, for example, a food product, or other contents, whether they be solid, semi-solid or liquid. Also, secondary devices as described above, such as temperature sensors, gauges, thermocouples and RTD's may be disposed more intimately with the contents or conditions that are being monitored.

A heating tray 100 may also be positioned in a mold, over molded, or both, to form a selected molded heated structure. Some plastics may be energized prior to and/or during over molding for improved bonding with the over molded material. A heating tray 100 may optionally be thermoformed to conform to at least a part of the mold structure and to preferentially align the resistance heating element within the mold. Once the heating tray is positioned within a mold, the resistance heating element 10 of the heating tray 100 may be energized to soften the thermoplastic sheets, and the heating tray may be over molded with a thermoplastic. The energizing and overmolding may be timed such that the thermoplastic sheets and over molded thermoplastic form a substantially homogenous structure when solidified. Alternatively, the thermoplastic sheets may be allowed to soften as a result of mold flow alone. The thermoplastic materials of the sheets and over molded thermoplastic are preferably matched to further facilitate the creation of a homogenous structure. The supporting substrate 11 may also be selected to be a thermoplastic to better promote the formation of a homogenous structure. The energizing may be timed to soften the thermoplastic sheets before, after, or during the overmolding process, depending upon the standard molding parameters, such as the flow characteristic of the selected thermoplastics, the injection molding fill time, the fill velocity, and mold cycle. The assembly is also amenable to other molding processes, such as injection molding, compression molding, thermoforming, and injection-compression molding.

Figures 9, 10, and 11 illustrate an exemplary heating element assembly which may be formed into a heating tray 100 final element assembly. Figure 9 is a top plan view of an exemplary resistance heating element 400. The resistance heating element 400 includes a supporting substrate 405 shaped in the profile of a flattened container. The profile may either be initially shaped in this profile shape or cut to the profile shape from a larger supporting

substrate. Resistance heating material is affixed to the supporting substrate 405 and is preferably resistance wire 410 sewn to supporting substrate 405.

The resistance heating element 400 shown in Figure 9 includes a plurality of flap portions 420 capable of rotation about a first axis of rotation indicated generally at fold lines 425. The circuit path 415 formed by resistance wire 410 continues onto flap portions 420 and terminates at terminal end portions 412.

Figure 10 is a top plan view of a heating element assembly 500. The resistance heating element 400 is laminated between two thermoplastic sheets, only the top sheet 505 of which is shown, to form a reformable continuous element structure. A portion of the thermoplastic sheet 505 is shown removed in order to show the resistance heating element 400.

The dashed lines 530 indicate portions of the laminated structure that may be removed, such as by stamping or die cutting, from the laminated structure to leave a foldable profile which may be formed into the a non-planar tray 600 shown in Figure 11. The remaining dashed lines of Figure 11 indicate fold lines.

A heating tray 600 may be formed by folding the heating element 500 along the dashed lines of Figure 10 and in the direction of the arrows shown in Figure 11. The flaps 420 of the resistance heating element 400 are laminated between thermoplastic layers and are folded into the tray shape shown in Figure 11. The folding step may include rethermalizing the thermoplastic structure while folding in order to thermoform the structure into the desired heat planes, or, alternatively, folding the thermoplastic structure into the desired heat planes and then rethermalizing the structure, although it is recognized that the latter method introduces residual stresses in the bend areas.

In the embodiment shown in Figure 11, the heating tray is formed with outwardly flared sides. This feature permits multiple trays to be stacked in nested engagement, which reduces spatial requirements for both storage and shipping.

It should be apparent that the heating tray 600 can optionally provide heat on five different interior planes may, but is formed from an easily manufactured planar heating element 500. It should further be apparent that the present invention is not limited in any way to the heating tray configuration 600 or heating element 500 described above. Rather, the above described method of manufacturing and heating element structure may be used to forms cups, enclosed containers, boxes, or any other structure which may be formed from a planar profile. The heating trays and other configurations can include planar elements made from resistance heating wires, scrim, woven and nonwoven fabric and conductive filing such as conductive polymers, inks and foils. Such planar forms should have sufficient tensile strength to resist mechanical distortion of the circuit path, or heater distribution profile,

during forming of the final product.

A sheet of heating element assemblies and a method of manufacturing the same is described hereafter. In another exemplary embodiment of the present invention, a sheet of heating element assemblies 225 is provided, as shown in Figure 7. The sheet of heating element assemblies 225 includes first and second affixed thermoplastic sheets, as described above, and a sheet of resistance heating elements 200 (Figure 8) secured between and to the first and second thermoplastic sheets. Essentially, the sheet of resistance heating elements 200 comprises a plurality of connected resistance heating elements 10. The sheet of resistance heating elements 200 comprises a supporting substrate 205 and a plurality of spaced pairs of circuit paths 207, each of the spaced pairs of circuit paths comprising at least one electrical resistance heating material attached to the supporting substrate 205 to define a pair of circuit paths, at least one of which includes a pair of terminal end portions 209, 210. The shape of the circuit paths 207 is merely illustrative of circuit path shapes, and any circuit path shape may be chosen to support the particular end use for a heating element assembly included in the sheet of heated element assemblies 225. Alternatively, conductive polymers or fabrics made from resistance heating material could be employed. The dashed lines of Figure 8 indicate where an individual resistance heating element may be removed from the sheets of resistance heating elements 225.

A sheet 225 of heating element assemblies may be manufactured using conventional mass production and continuous flow techniques, such as are described in U.S. Patent No. 5,184,969 to Sharpless et al., the entirety of which is incorporated herein by reference. For example, as illustrated in Figure 7, first and second thermoplastic sheets 210, 212 may be provided from a source, such as rolls 214, 216 of thermoplastic sheets, or extruded using known extrusion techniques as a part of the manufacturing process. One manufacturer of such thermoplastic sheet extruders is Killion Extruders Inc. of Cedar Grove, New Jersey. Likewise, a sheet of resistance heating elements 200 may be provided from a source, such as roll 218. Sheet 200 may be manufactured as described above in the "Sewing Operation" section. The sheets 200, 212, 214 may be made to converge, such as by rollers 224, between a heat source, such as radiant heating panels 220, to soften the thermoplastic sheets 210, 212. A series of rollers 222 compresses the three sheets 200, 212, 214 into a sheet of heated element assemblies 225, thereby also removing air from between the sheets 200, 212, 214. The rollers 222 may also provide heat to help fuse the sheets 200, 212, 214 and/or may be used to cool freshly laminated sheets 200, 212, 214 to help solidify the heated sheets into the sheet of heated element assemblies 225 after compression.

It should be apparent that a sheet of a plurality of multiple-layered heating element assemblies, such as a sheet including a plurality of heating element assemblies 100a of Figure

6, may also be manufactured simply by including a third thermoplastic sheet and a second sheet of resistance heating elements to the process described above.

Regardless of the specific manufacturing technique, the sheet of heating element assemblies 225 may be collected into a roll 230. The roll 230 may then be used by an original equipment manufacture (OEM) for any desired manufacturing purpose. For example, the OEM may separate or cut individual heating element assemblies from the roll and include the heating element assembly in a desired product, by molding, adhesive or ultrasonic bonding, for example, into, a container or molded product. An individually manufactured heating element assembly as mentioned above or a heating element assembly removed from a sheet of heating element assemblies 225 , because of its resiliency and good mechanical properties, is amenable to secondary manufacturing techniques, such as die cutting, stamping, or thermoforming to a desired shape or combination thereof as described above. Each heating element assembly may be cut or stamped into a preselected shape for use in a particular end product even while still a part of sheet 225 and then collected into a roll 230. The circuit paths of the resistance heating element of the heating element assembly may be appropriately shaped to conform to the desired shape of a selected product and heat planes in which the heating element assembly is to be included or formed.

The formable semi-rigid feature of the heating element assemblies of the present invention provides a designer the opportunity to include the assembly in complex heat planes. The assembly may be cut to a desired formable shape, and the circuit path is preferably designed to substantially conform to this shape or the desired heat planes. The assembly may then be rethermalized and folded to conform to the heat planes designed for the assembly to occupy.

A preferred thermoplastic sheet may range from approximately 0.004 inch to 0.100 inch. Thus, the thickness of the thermoplastic sheets of a heating element assembly may be chosen to effectively bias heat generated by a resistance heating element in a selected direction. The supporting substrate itself also may provide an insulation barrier when the circuit path is oriented towards, for example, contents to be heated and the supporting substrate is oriented toward an outer or gripping surface.

Similarly, one or both of the thermoplastic sheets of a heating element assembly 100 or heating element assembly 500 may be coated with a thermally conductive coating that promotes a uniform heat plane on the heated element assembly. An example of such a coating may be found on anti-static bags or Electrostatic Interference (ESI) resistive bags used to package and protect semiconductor chips. Also, thermally conductive, but preferably not electrically conductive, additive may be added to the thermoplastic sheets to promote heat distribution. Examples of such additive may be ceramic powders, such as, for example,

Al_2O_3, MgO, ZrO_2, boron nitride, silicon nitride, Y_2O_3, SiC, SiO_2, TiO_2, etcetera. A thermally conductive layer and/or additive is useful because a resistance wire typically does not cover all of the surface area of a resistance heating element 10.

A heated lid 700, shown in Figures 13 and 14, may optionally be provided for use in connection the foregoing tray configuration. The lid may be formed with one or more resistance heating circuits constructed using the same techniques previously described. In the embodiment shown, the lid 700 has a planar construction and comprises a single resistance heating circuit 710 in a serpentine configuration. The resistance heating 710 circuit is provided with terminal end portions 708, 709.

Advantageously, a heating assembly, formed in accordance with the invention, may be provided having varying surface watt densities. For example, with reference to Figure 12, a heating assembly, which may be reformed into a heating tray, is provided with a surface watt density of 3 W/in ^{2} on the surface forming the bottom of the heating tray, and a surface watt density of 1 W/in ^{2} on the peripheral surfaces forming the sides of the heating tray.

Alternatively, in situations where the thermal energy provided by a resistance heating element can exceed the thermal limits of laminate or over molding materials, one or more metal sheets, which are preferably stainless steel, may be attached to the resistance heating element layer as a both a stiffening agent and a thermal conductor. Further, the metal sheet may be over molded, optionally leaving a portion of the metal sheet exposed, preferably, in the region of highest watt density. By employing metal sheeting in the heating assembly construction, a surface watt density of up to at least 8 W/in ^{2} is achievable on the surface forming the bottom of the tray, and at least 2/W/in ^{2} on the tray sides, without compromising the integrity of the tray, and, in particular, the plastic layers formed therein.

Surfaces forming the bottom and sidewalls of the heating tray are also provided with a 0.25 inch frame in which resistance heating wires are substantially absent.

Experimental Results

A heating tray and corresponding lid were formed by laminating resistance heating circuits between thermoplastic sheets. The thermoplastic material used for both the lid the tray assemblies was ULTEM 1000. The heating tray was formed with two sheets of ULTEM 1000 having a total thickness of 0.02 inch on either side of a wire scrim. Thus, a total of 0.040 inch of thermoplastic was utilized in the tray construction. The heating tray was formed comprising two resistance heating circuit paths sandwiched between laminated layers of thermoplastic. The resistance heating circuit path used for temperature boosting was formed using resistance heating wire having a total impedance of 352.87 Ohms. The resistance heating circuit path used for maintenance heating was formed using resistance heating wire

having a total impedance of 279.68 Ohms. Each resistance heating wire may comprise a plurality of twisted, braided or parallel individual wires having a collective diameter of between about 0.010 inch to 0.050 inch. Both resistance heating wires were sewn to a fiberglass scrim substrate having an uncompressed thickness of approximately 0.030 inch. Substrates may range from about 0.005 inch to 0.030 inch thickness.

The tray lid was formed by laminating a single resistance heating circuit between thermoplastic sheets, the thermoplastic sheets having a total thickness of 0.020 inch on the bottom of a wire scrim and 0.095 inch on the top of the wire scrim, for a total thickness of 0.115 inch. The resistance heating circuit path was formed using resistance heating wire having an impedance of 363.27 Ohms. The resistance heating wire was sewn to a fiberglass scrim substrate having an uncompressed thickness of approximately 0.030 inch. It will be understood that materials used in forming the heating tray and lid are not limited to the precise thicknesses defined herein, which are merely provided by way of example.

The heating tray and lid were both similarly manufactured. In each case, a substrate, having a resistance heating wires sewn thereto, was placed between the top and bottom thermoplastic sheets to form a heating element assembly. Next, the heating element assembly was sandwiched in a manufacturing assembly. To this end, a Teflon sheet was placed adjacent to the exposed surface of each thermoplastic sheet, a layer of silicon rubber was placed adjacent each Teflon sheet, and a stainless steel plate was placed adjacent each silicon rubber sheet. The Teflon prevents the thermoplastic sheets from adhering to the manufacturing assembly, while the silicon rubber sheets provide a cushion which allows for even distribution of the hydraulic pressure applied bt the heat press. The stainless steel sheets act as stiffening agents to facilitate handling of the otherwise pliable assembly.

The resulting manufacturing assembly was then placed in a conventional heated press, with temperature platens preheated to 450 degrees Fahrenheit. The assembly was heated for 15 minutes at a pressure of 12,000 lbs. The assembly was then air cooled for 20 minutes, followed by a 2 minute water cooling period. The heater was then trimmed to final dimensions using a belt sander.

In the case of the heating tray, any additional fabrication step was required. After forming and cooling the heating element assembly, the assembly was reheated along bend lines, about which the flap portions of the assembly were folded to reform the assembly into a heating tray.

Performance graphs for the above-described heating tray are shown in Figure 15 and 16. In each case the heating tray was placed on two laterally spaced wood strips, each having a width 0.75 inch. Figure 13 shows a performance graph of the heating tray in an unloaded state. Figure 14, by comparison, shows a heating tray with lid, the tray having a thin foil pan

of frozen lasagna contained therein. The plot shows the lasagna stabilized at a temperature of 204 degrees Fahrenheit in 6 hours. The boost heat was turned off at 5 hours and 23 minutes. The maximum temperature of the heater was 318 degrees Fahrenheit.

Advantages of the Invention

A heating tray in accordance with the invention provides more efficient heating of food products. Indeed, experimental results have shown that the present invention consumes 1/3 less wattage than traditional heating methods. This significant power savings is attributed in part to the intimate contact achievable between the heating tray and the food product as compared to conventional heating methods. Another factor attributing to improved heating efficiency is the ability to design and manufacture the product with a varied heat density, thereby allowing the accurate placement of heat such that the food product can evenly warmed throughout, while preventing over warming or burning of food product.

Also, the heating tray is hermetically sealed, making the tray suitable for direct contact with food products, and allowing for the utilization of conventional cleaning techniques such as dishwashers etcetera, without compromising the integrity of the tray.

Yet another advantage of the invention is the aligning geometry of the tray design that allows for nested stacking of several trays, which reduces tray storage and transport requirements.

Further, as described above, the heating tray of the present invention lends itself to many automated and secondary manufacturing techniques, such as stamping, die cutting, and overmolding, to name a few. Designers can easily choose thermoplastics and other materials for their designs that meet required RTI (relative thermal index) requirements for specific applications by following standard design techniques and parameters set by materials manufacturers Also, heating trays such as described above allow the food industry to efficiently and effectively reheat prepared foods, as is often required of businesses that operate large or small food service venues or that purchase from distributors of prepared foods. Also, among the many advantages of the present invention is the ability to intimately locate a secondary device between the thermoplastic sheets. For example, a memory device or other data collector may be positioned within close proximity to a food product, thereby allowing more accurate data collection, such as disclosed in commonly owned U.S. Patent No. 6,417,335, herein incorporated in its entirety by reference. This data, as an example, may be used to prove that a food was prepared at a temperature and for a time period sufficient to kill the E. coli bacteria.

Although various embodiments have been illustrated, this is for the purpose of describing, but not limiting the invention. The assembly line described above is merely

illustrative of one means of forming a sheet of heated element assemblies. Further, the supporting substrate shapes and circuit paths described above and shown in the drawings are merely illustrative of possible circuit paths, and one of ordinary skill should appreciate that these shapes and circuit patterns may be designed in other manners to accommodate the great flexibility in uses and number of uses for the heating element assembly of the present invention. Therefore, various modifications which will become apparent to one skilled in the art, are within the scope of this invention described in the attached claims.

We claim:

1. A method of manufacturing a heating tray, comprising the steps of:

(a) disposing a plurality of resistance heating elements between first and second thermoplastic sheets, each of the resistance heating elements forming a circuit path;

(b) laminating the first and second thermoplastic sheets such that each of the resistance heating elements is secured between the first and second thermoplastic sheets to form a reformable structure; and

(c) forming the reformable structure into a heating tray.

2. The method of claim 1 wherein the reformable structure further comprises:

at least one flap portion capable of rotation about a first axis of rotation, at least one of the circuit paths continuing onto the flap portion, wherein the step of forming includes rotating the at least one flap portion about the first axis to provide resistance heating in at least two planes.

3. The method of claim 1, wherein said step of laminating includes the steps of heating said thermoplastic sheets and compressing said thermoplastic sheets to laminate the resistance heating elements between the thermoplastic sheets.

4. The method of claim 1, wherein said step of forming includes the step of thermoforming the reformable structure into a heating tray.

5. The method of claim 1, wherein the first and second thermoplastic sheets form part of a thermoplastic bag and the step of laminating the first and second thermoplastic sheets includes the steps of evacuating air from the bag to compress the bag around the resistance heating elements and applying heat and pressure to the bag to fuse the first and second thermoplastic sheets and secure the resistance heating elements within said bag.

6. The method of claim 1, further comprising the step of cutting the reformable structure into a foldable profile before forming the reformable structure into the heating tray.

7. The method of claim 1, wherein said step of providing the first and second thermoplastic sheets includes providing a tubular-shaped thermoplastic body including the first and second thermoplastic sheets and the step of disposing the resistance heating elements

includes the step of disposing the resistance heating elements within the tubular-shaped thermoplastic body.

8. The method of claim 1, further comprising the steps of:

(d) energizing at least one of the resistance heating elements to soften the thermoplastic sheets; and

(e) overmolding the heating tray with a thermoplastic, the steps of energizing and overmolding timed such that the thermoplastic sheets and over molded thermoplastic form a substantially homogenous structure.

9. The method of claim 1, wherein the plurality of resistance heating elements is supported by a substrate.

10. A method of manufacturing a heating element assembly, comprising the steps of:

(a) disposing a plurality of resistance heating elements between first and second thermoplastic sheets, the resistance heating elements being attached to a supporting substrate and forming a plurality of circuit paths,

(i) at least one of the circuit paths having terminal end portions,

(ii) at least one of the circuit paths continuing onto a first flap portion of the resistance heating element assembly capable of rotation about a first axis of rotation; and

(b) laminating the first and second thermoplastic sheets such that the plurality of resistance heating elements is secured between the first and second thermoplastic sheets to form a heating element assembly.

11. The method of claim 10, wherein said step of laminating includes the steps of heating the thermoplastic sheets and compressing the thermoplastic sheets to laminate said resistance heating elements between the thermoplastic sheets.

12. A method of manufacturing a sheet of heating element assemblies, comprising the steps of:

(a) disposing at least one sheet of resistance heating elements between first and second thermoplastic sheets, the resistance heating elements being attached to a supporting substrate, and forming a plurality of circuit paths in spaced apart pairs, at least one each pair of circuit paths having terminal end portions; and

(b) laminating the first and second thermoplastic sheets such that the at least one

sheet of resistance heating elements is secured between the first and second thermoplastic sheets to form a sheet of heating element assemblies,

wherein at least one of each pair of circuit paths continues onto a first flap portion of the heating element assembly capable of rotation about a first axis of rotation.

13. The method of claim 12, further comprising the steps of removing at least one heating element assembly from the sheet of heating element assemblies, the removed heating element assembly being a reformable structure, and forming the reformable structure into a final element assembly configuration wherein at least the first flap portion of the resistance heating element is rotated about the first axis to provide resistance heating in at least two planes.

14. The method of claim 13, further comprising the step of cutting at least one of the heating element assemblies into a foldable profile before forming the reformable structure into the final element assembly configuration.

15. The method of claim 12, further comprising the steps of removing at least one heating element assembly from the sheet of heating element assemblies, the heating element assembly being a reformable structure, and forming the reformable structure into a final element assembly configuration wherein at least the first flap portion of the resistance heating element is rotated about said first axis to provide resistance heating in at least two planes.

16. The method of claim 14, wherein said step of cutting includes the step of one of stamping and die cutting at least one of the heating element assemblies into the profile.

17. The method of claim 12, wherein said step of disposing a said sheet of resistance heating elements between first and second thermoplastic sheets includes extruding a tubular-shaped thermoplastic body including said first and second thermoplastic sheets and disposing said sheet of resistance heating elements within said tubular-shaped thermoplastic body.

18. A heating element assembly, comprising:

(a) a first thermoplastic sheet;

(b) a second thermoplastic; and

(c) a plurality of resistance heating elements disposed between the first and second thermoplastic sheets and forming a plurality of circuit paths, the thermoplastic sheets and resistance heating elements being attached together to form a reformable structure, at least one of the circuit paths having terminal end portions, at least one of the circuit paths

continuing onto a first flap portion of the reformable structure, capable of rotation about a first axis of rotation, wherein, the reformable structure formed into a final element assembly configuration where the flap portion is rotated about the first axis to provide resistance heating in at least two planes.

19. The heating element assembly of claim 18, wherein the thermoplastic sheets are attached with an adhesive.

20. The heating element assembly of claim 18, wherein the thermoplastic sheets are attached by one of fusing and laminating.

21. The heating element assembly of claim 18, wherein the reformable structure is thermoformed into said final element assembly configuration.

22. The heating element assembly of claim 18, wherein the reformable continuous structure is cut into a foldable profile.

23. The heating element assembly of claim 18, wherein the electrical resistance heating material is at least one of glued, sewn and fused to the supporting substrate.

24. The heating element assembly of claim 21, wherein the electrical resistance heating material is sewn to said supporting substrate with a thread.

25. The heating element assembly of claim 18, wherein the supporting substrate comprises at least one of a woven and non-woven fibrous layer.

26. The heating element assembly of claim 18, wherein the supporting substrate is a thermoplastic sheet.

27. The heating element assembly of claim 18, wherein the supporting substrate includes thermally conductive additives.

28. The heating element assembly of claim 18, wherein at least one of the thermoplastic sheets includes a thermally conductive coating.

29. The heating element assembly of claim 18, further comprising a secondary device

secured between the first and second thermoplastic sheets.

30. The heating element assembly of claim 18, wherein the heating element assembly is over molded with a thermoplastic such that the over molded thermoplastic and thermoplastic sheets form a substantially homogenous structure.

31. The heating element assembly of claim 18, wherein at least one the pair of predetermined circuit paths is a continuous loop, which is capable of being energized by at least one of high frequency radiation and magnetic induction.

32. The heating element assembly of claim 29, wherein the secondary device is one of, a thermistor, a sensor, a RTD and a thermocouple.

33. The heating element assembly of claim 18, wherein at least one of the thermoplastic sheets is Polyetherimide.

34. The heating element assembly of claim 18 wherein the final element assembly is hermetically sealed.

35. The heating element assembly of claim 18, wherein element assembly has a bottom and the circuit path density in the bottom of the element assembly is greater than the circuit path density in the flap portions.

36. The heating element assembly of claim 18, wherein the flap portions are outwardly flared to provide for nested engagement with a second identical heating assembly.

37. A method of manufacturing a sheet of heating element assemblies, comprising the steps of:

(a) disposing at least one sheet of resistance heating elements between first and second thermoplastic sheets, the resistance heating elements being attached to a supporting substrate, and forming a plurality of spaced pairs of circuit paths, at least one of each of the pairs of spaced circuit paths having terminal end portions, at least one of each of the pairs of the spaced circuit paths continuing onto a first flap portion capable of rotation about a first axis of rotation; and

(b) attaching the first and second thermoplastic sheets such that the at least one sheet of resistance heating elements is secured between the first and second thermoplastic

sheets to form a reformable structure.

38. The method of claim 37, wherein the step of attaching the first and second thermoplastic sheets includes attaching the first and second thermoplastic sheets with adhesive.

39. The method of claim 37, wherein the step of attaching the first and second thermoplastic sheets includes fusing and laminating the first and second thermoplastic sheets.

40. The method of claim 37 wherein the electrical resistance heating material is at least one of glued, sewn and fused to the supporting substrate.

41. The method of claim 37 wherein said electrical resistance heating material is sewn to said supporting substrate with a thread.

42. The method of claim 37 wherein the supporting substrate comprises at least one of a woven and non-woven fibrous layer.

43. The method of claim 37 wherein the supporting substrate is an extruded thermoplastic sheet.

44. The method of claim 37 further comprising a plurality of secondary devices, each of said secondary devices disposed between said first and second thermoplastic sheets and associated with one of said circuit paths.

45. The method of claim 37 wherein at least one of the thermoplastic sheets includes a thermally conductive coating.

46. A heating tray, comprising:

(a) a first thermoplastic sheet;

(b) a second thermoplastic sheet; and

(c) a resistance heating element disposed between the first and second thermoplastic sheets, the resistance heating element comprising:

(i) a supporting substrate containing a plurality of resistance heating circuit paths, at least one of the circuits paths having terminal end portions, at least one of the circuit paths continuing onto a first flap portion of a resistance heating element capable of

rotation about a first axis of rotation; and

(iii) a plurality of flap portions capable of rotation about a first axis of rotation, at least one of the circuit paths continuing onto at least a portion of each of the flap portions,

wherein the thermoplastic sheets and the resistance heating element are laminated together to form a reformable structure, the reformable structure formed into a final element assembly wherein the flap portions are rotated about the first axis to provide resistance heating in a plurality of planes.

47. The heating tray of claim 46, wherein said resistance heating material comprises at least one of Ni-Cr, conductive ink, fabric and scrim.

48. The heating tray of claim 46, wherein at least two of the plurality of circuit paths have different watt densities.

49 In combination a heating tray and heating lid,

the heating tray comprising:

(a) a first thermoplastic sheet;

(b) a second thermoplastic sheet; and

(c) a plurality of resistance heating elements disposed between the first and second thermoplastic sheets, the thermoplastic sheets and resistance heating elements being attached together to form a reformable structure, the resistance heating elements being attached to a supporting substrate and forming a plurality of circuit paths, at least one of the circuit paths having terminal end portions, at least one of the circuit paths continuing onto a first flap portion of the reformable structure, capable of rotation about a first axis of rotation; and

the heating lid comprising:

(d) a first thermoplastic sheet;

(e) a second thermoplastic sheet; and

(f) a plurality of resistance heating elements disposed between the first and second thermoplastic sheets, the thermoplastic sheets and resistance heating elements being attached together to form a reformable structure, the resistance heating elements being attached to a supporting substrate and forming a plurality of circuit paths, at least one of the circuit paths having terminal end portions.

* * *

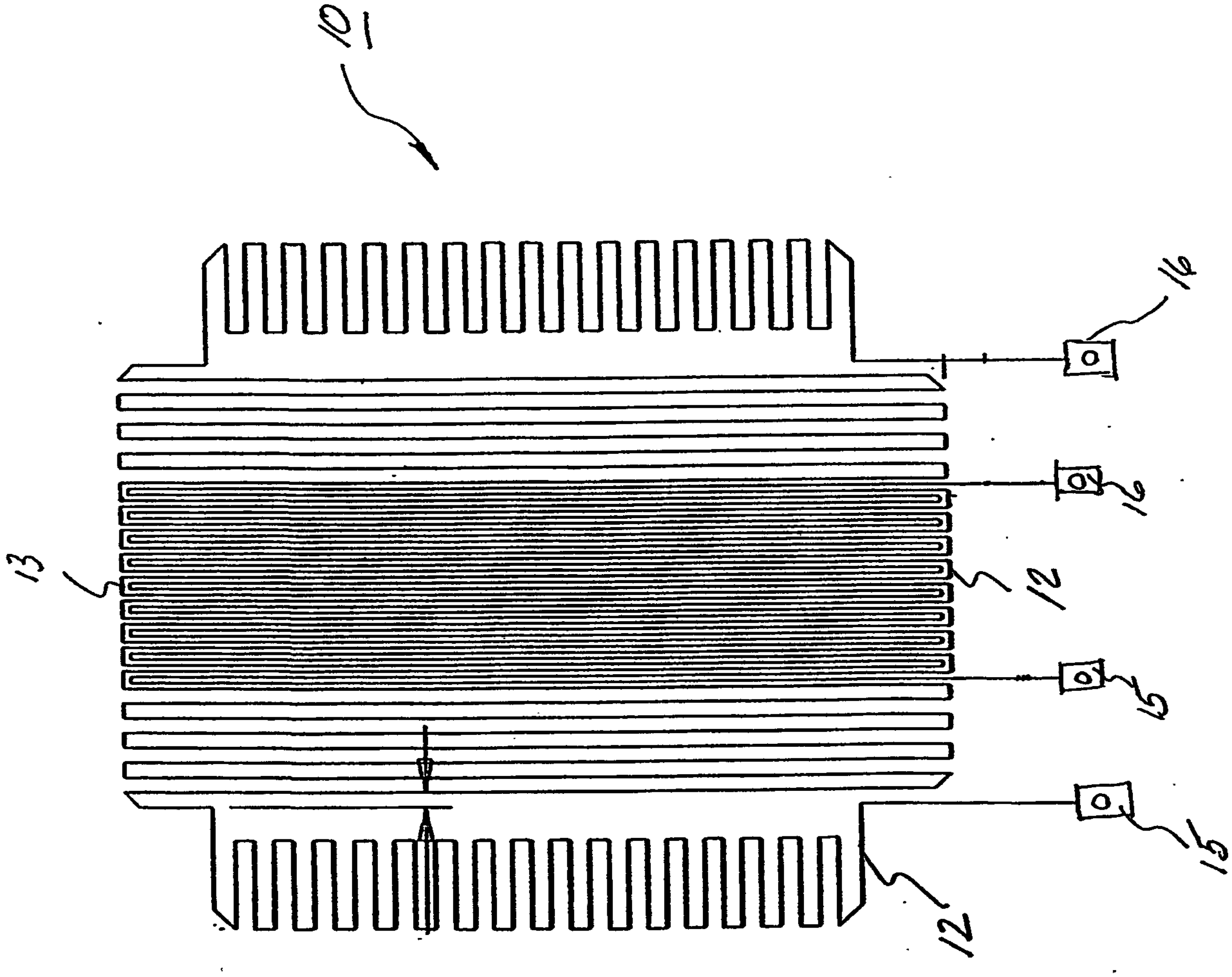

Figure 1

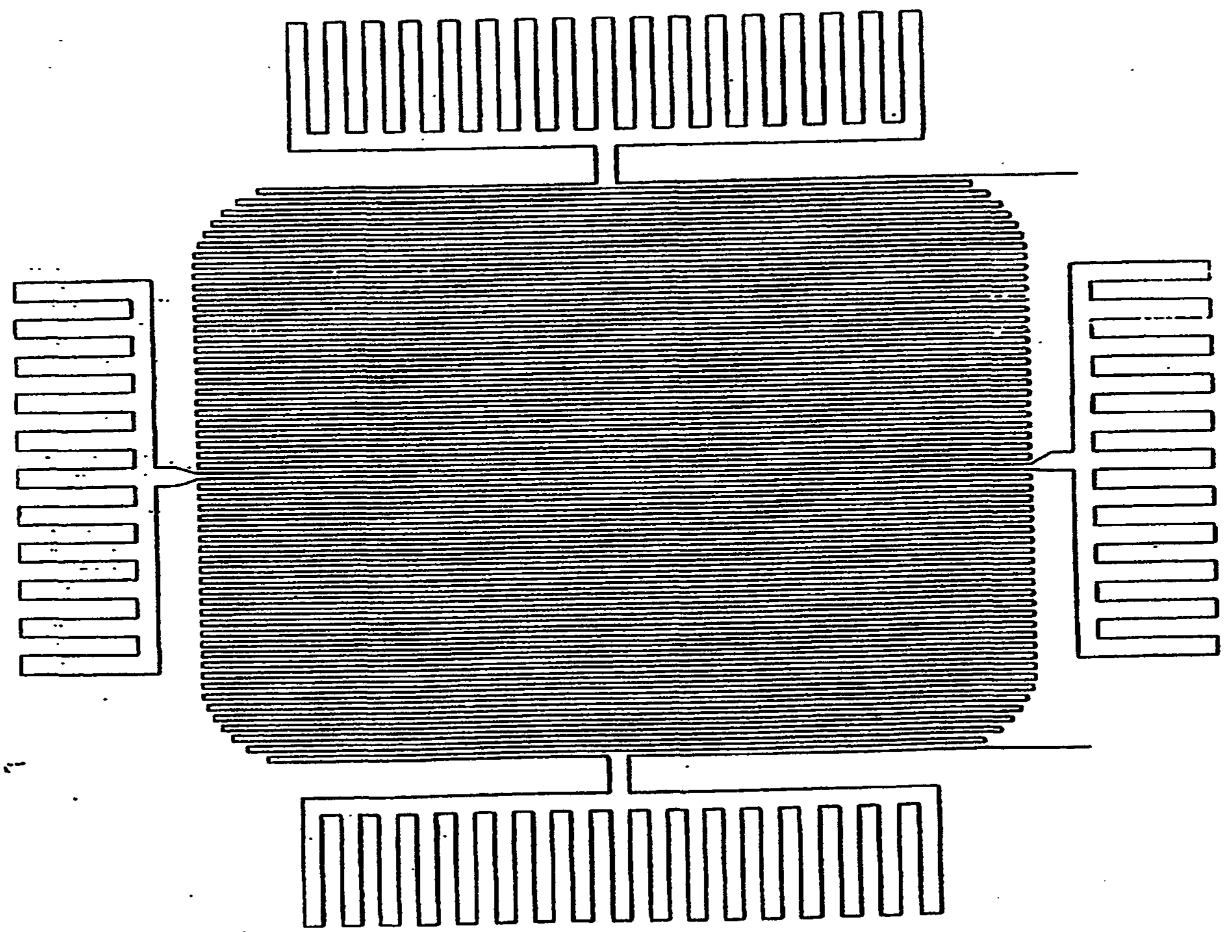

Figure 1a

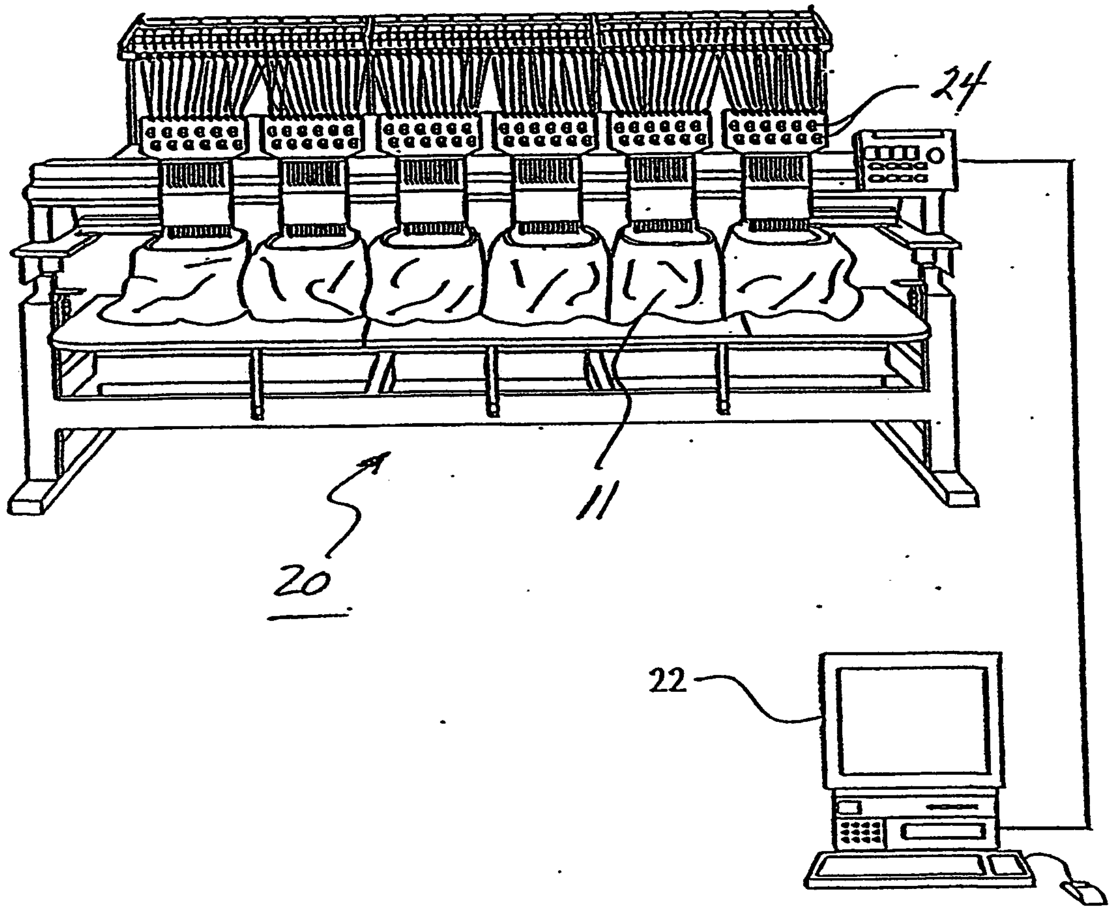

Figure 2

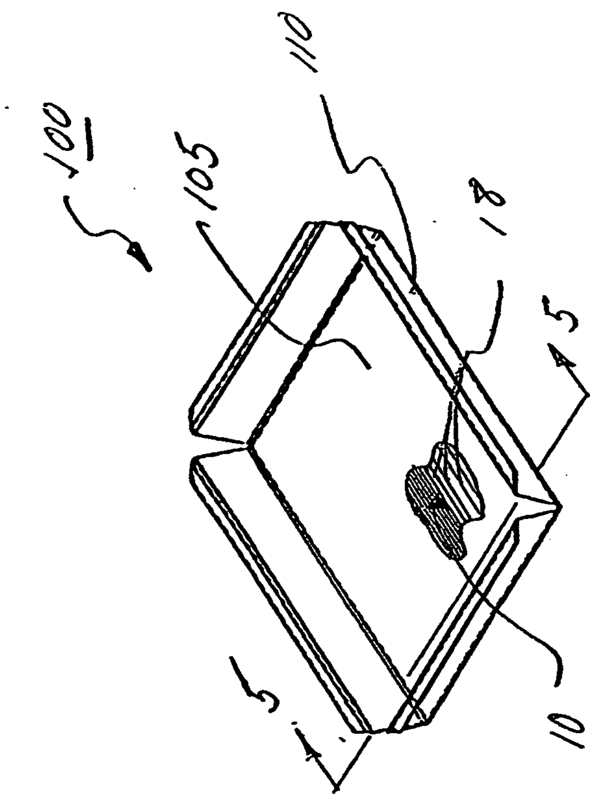

Figure 3

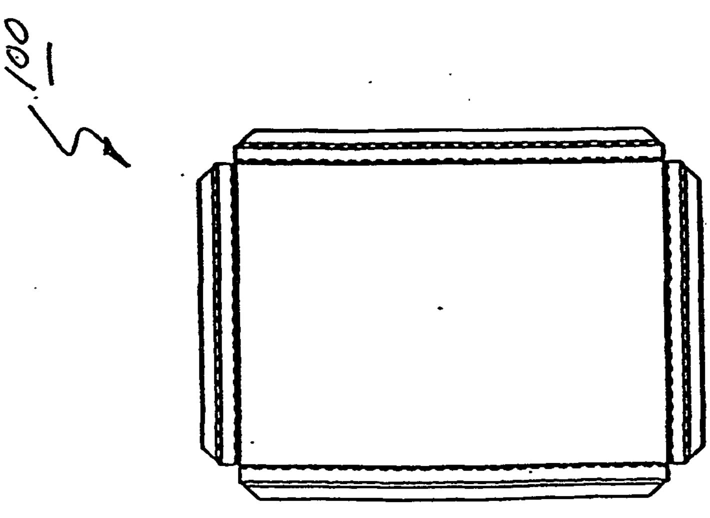

Figure 4

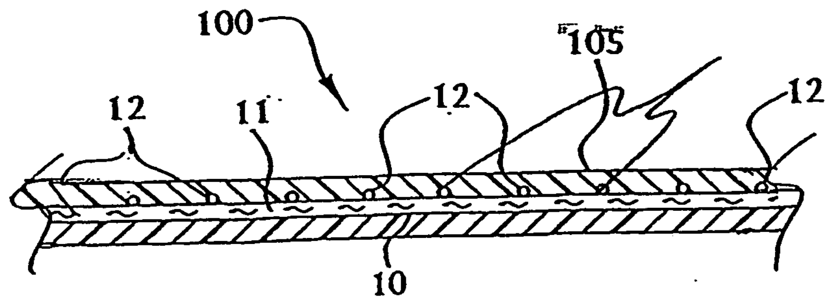

FIG. 5

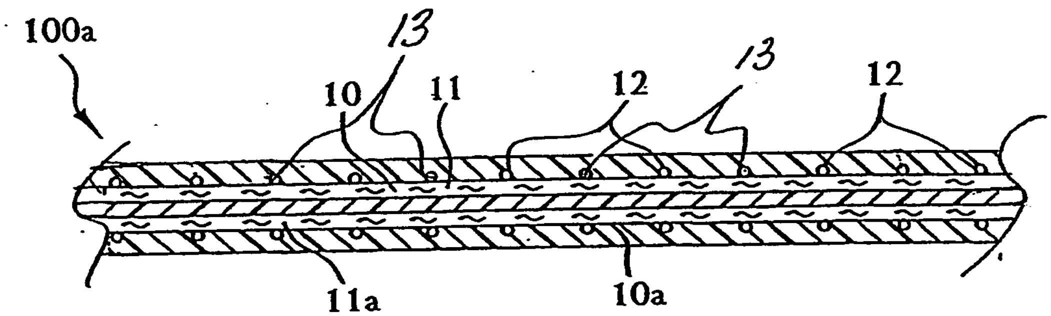

FIG. 6

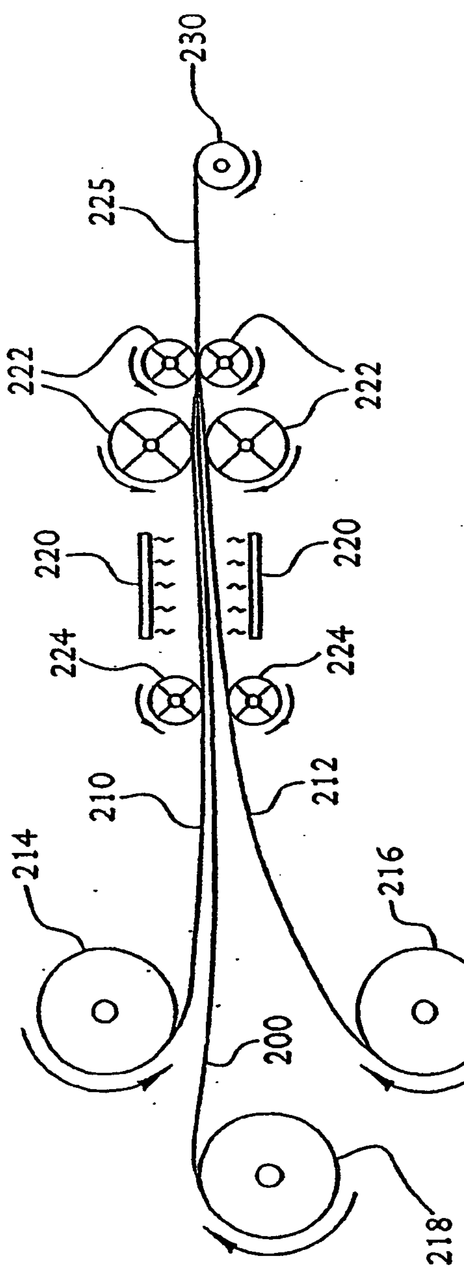

Figure 7

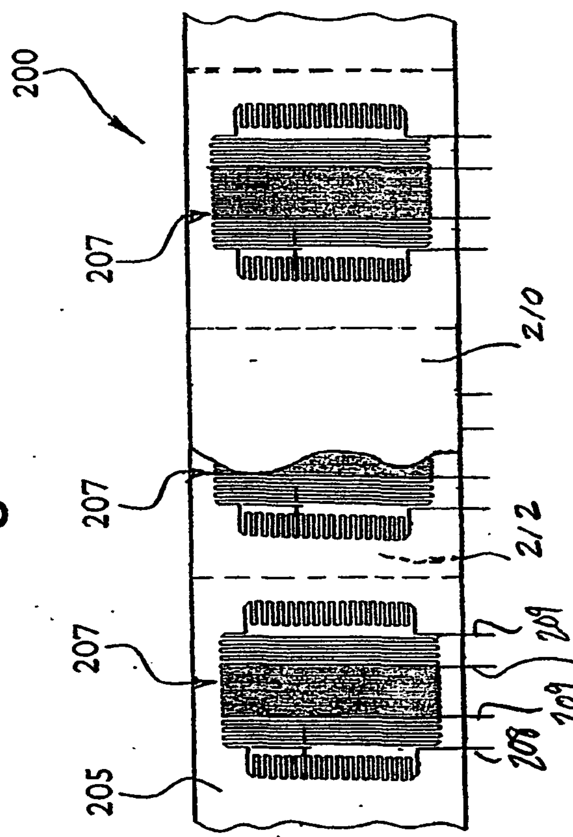

Figure 8

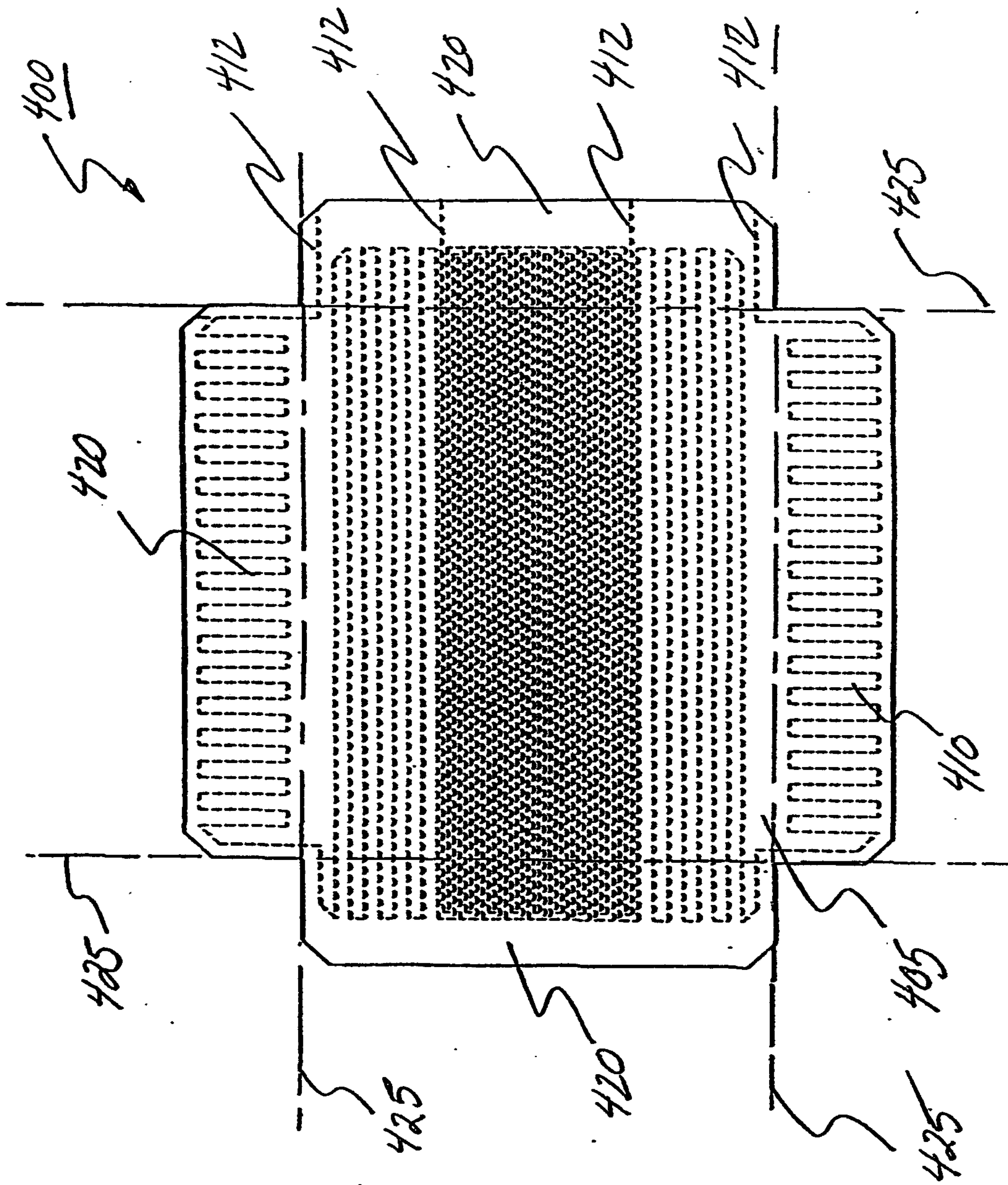

Figure 9

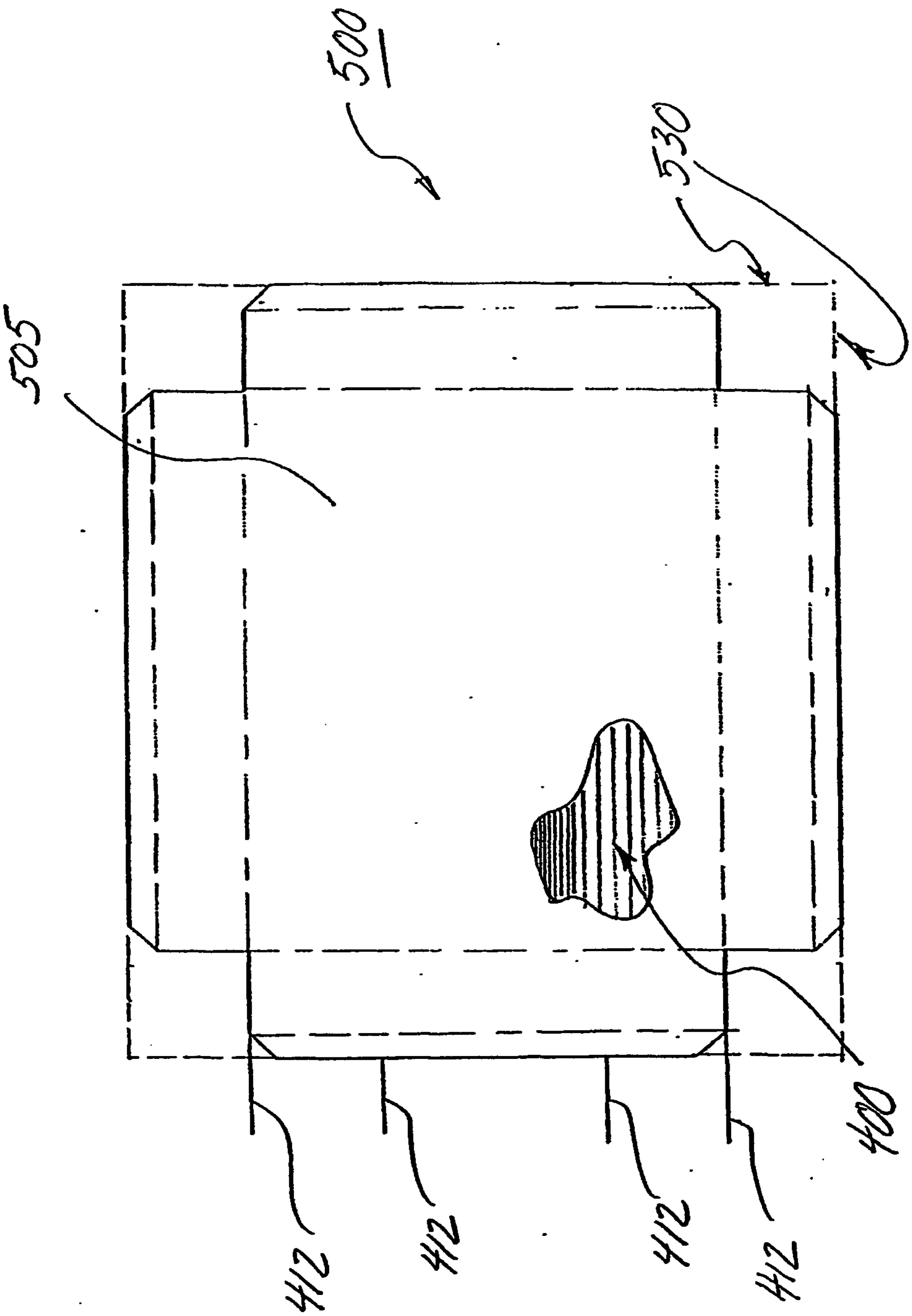

Figure 10

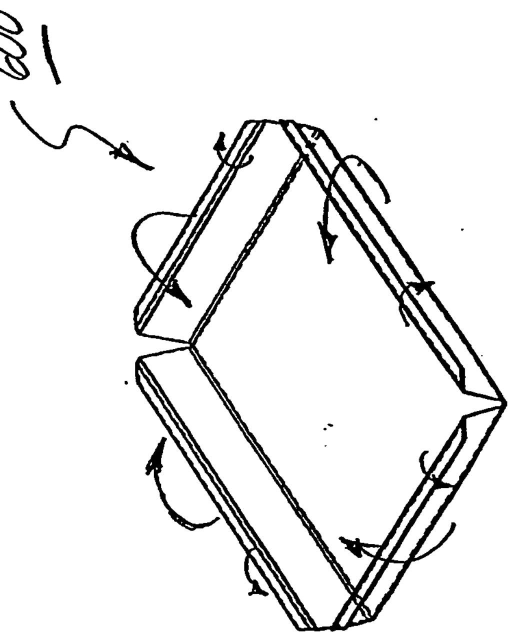

Figure 11

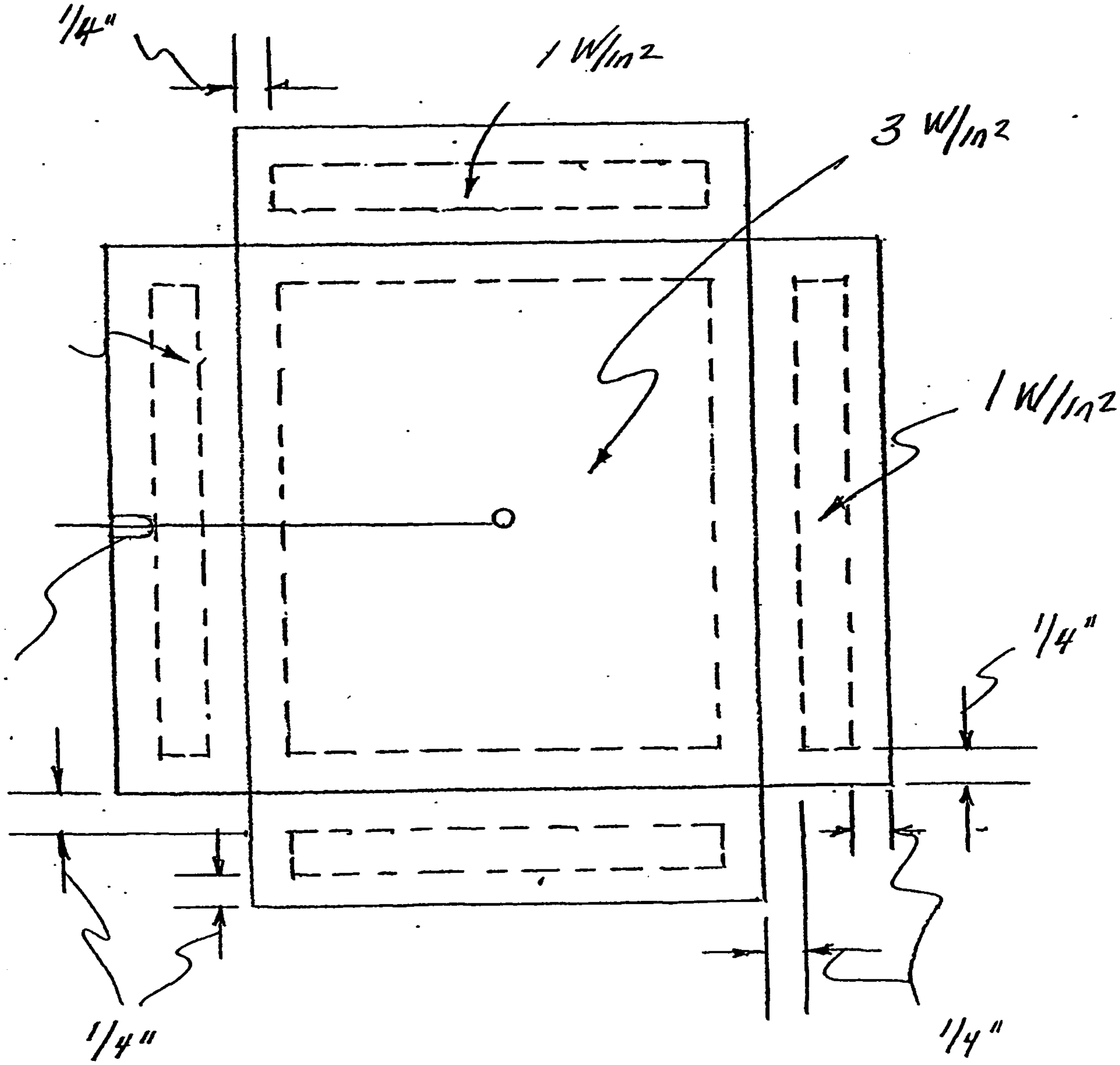

Figure 12

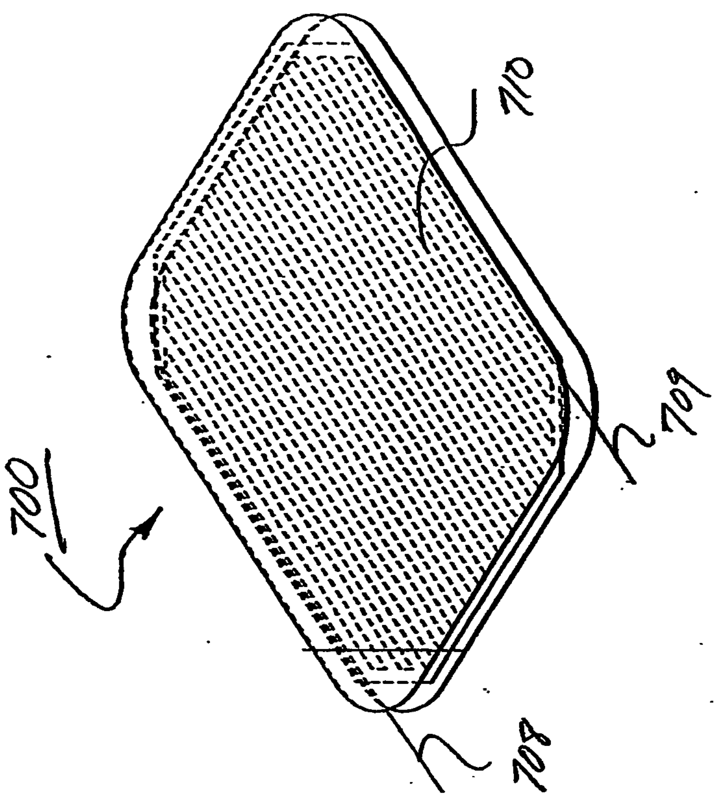

Figure 14

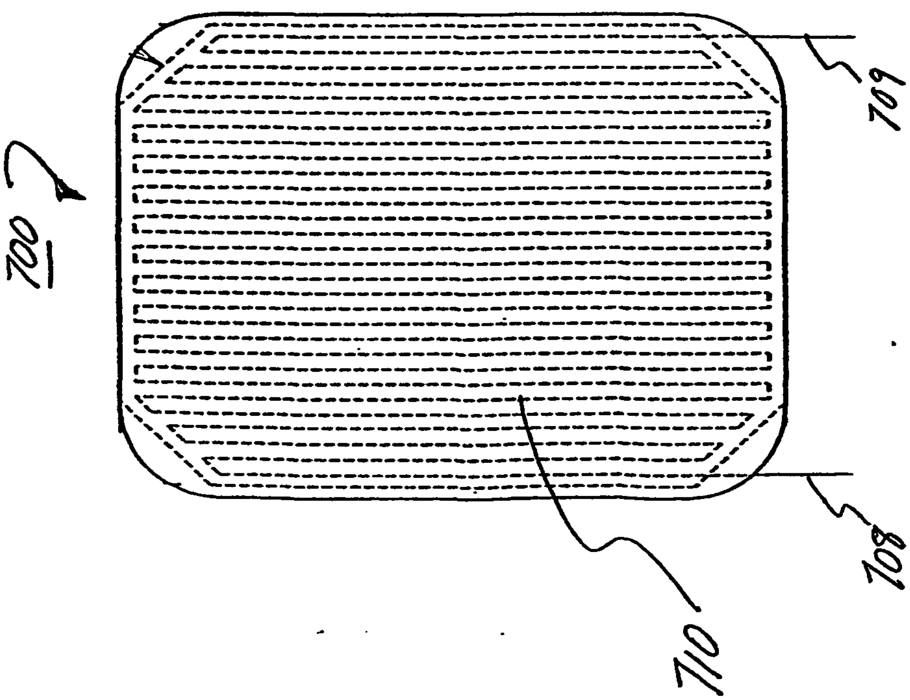

Figure 13

Heater Test Results

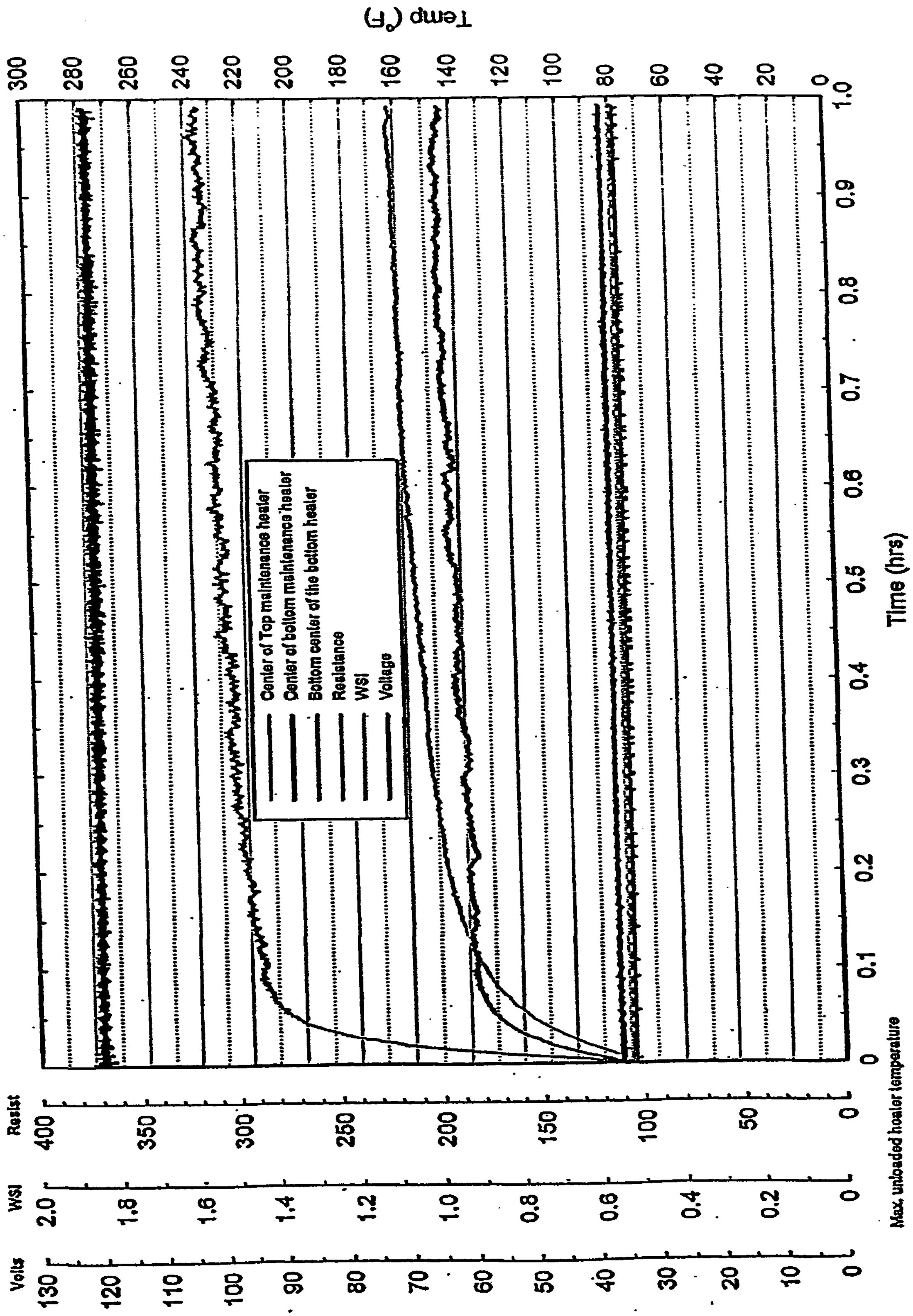

Figure 15

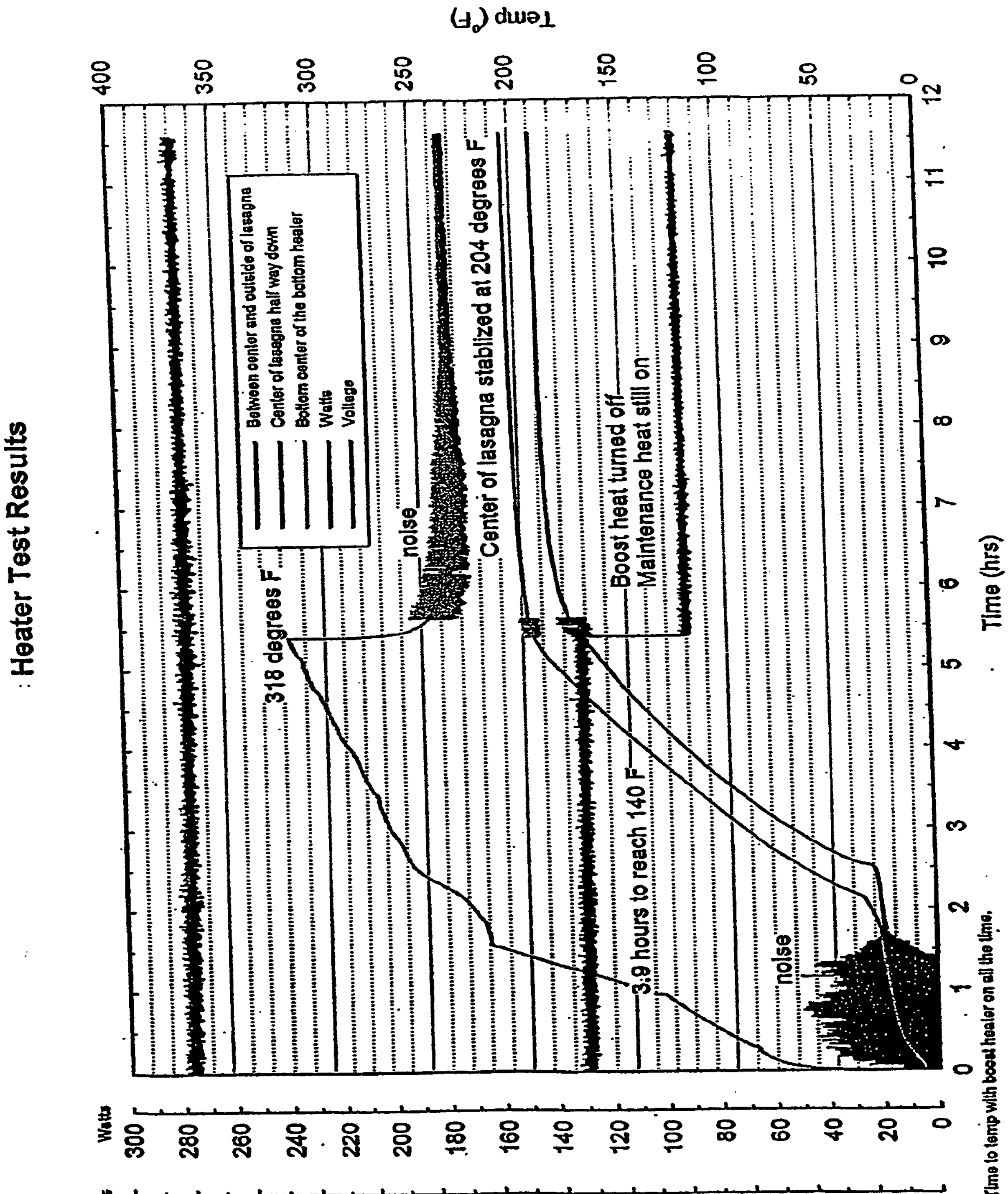
Heater Test Results
Temp (°F)
Time (hrs)
Volts
Watts
Between center and outside of lasagna
Center of lasagna half way down
Bottom center of the bottom heater
Watts
Voltage
318 degrees F
noise
Center of lasagna stablized at 204 degrees F
Boost heat turned off
Maintenance heat still on
3.9 hours to reach 140 F
noise
Time to temp with boost heater on all the time.

Figure 16